

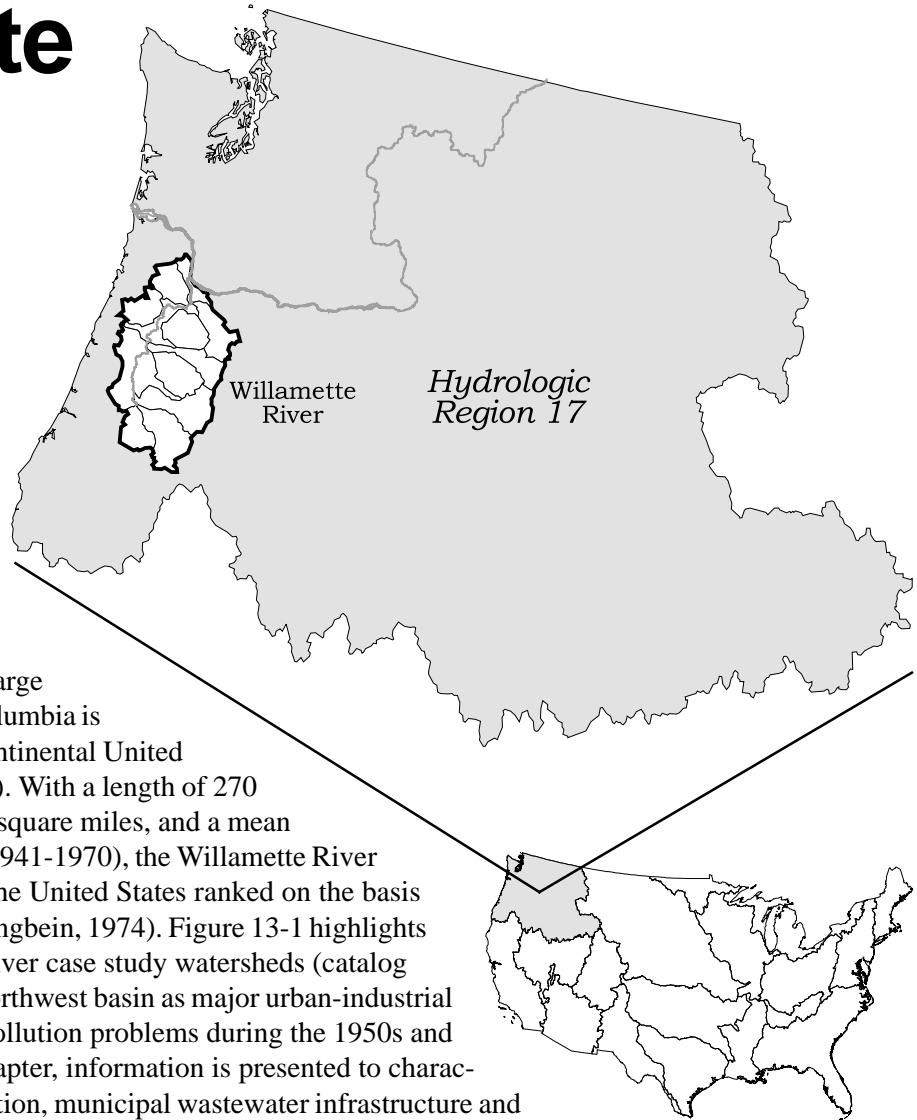
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# Chapter 13

## Willamette River Case Study

The Pacific Northwest basin, covering a drainage area of 277,612 square miles, includes the “mighty” Columbia River. Based on its annual discharge (262,000 cfs, 1941-1970), the Columbia is the second largest river in the continental United States (Iseri and Langbein, 1974). With a length of 270 miles, a drainage area of 11,200 square miles, and a mean annual discharge of 35,660 cfs (1941-1970), the Willamette River is the 15th largest waterway in the United States ranked on the basis of annual discharge (Iseri and Langbein, 1974). Figure 13-1 highlights the location of the Willamette River case study watersheds (catalog units) identified in the Pacific Northwest basin as major urban-industrial areas affected by severe water pollution problems during the 1950s and 1960s (see Table 4-2). In this chapter, information is presented to characterize long-term trends in population, municipal wastewater infrastructure and effluent loading of pollutants, ambient water quality, environmental resources, and uses of the Willamette River. Data sources include USEPA’s national water quality database (STORET), published technical literature, and unpublished technical reports (“grey” literature) obtained from local agency sources.

The Willamette River extends for 270 miles from its headwaters in the southern Cascade Mountains in Douglas County, Oregon, to the city of Portland, Oregon, where it meets the tidal Columbia River (Figure 13-2) (Iseri and Langbein, 1974). More than two-thirds of Oregon’s population lives within the major urban centers that have developed in the valley. The basin provides extensive natural habitat for fish and wildlife and supports a prosperous economy based on agriculture, timber and wood products, and recreation.

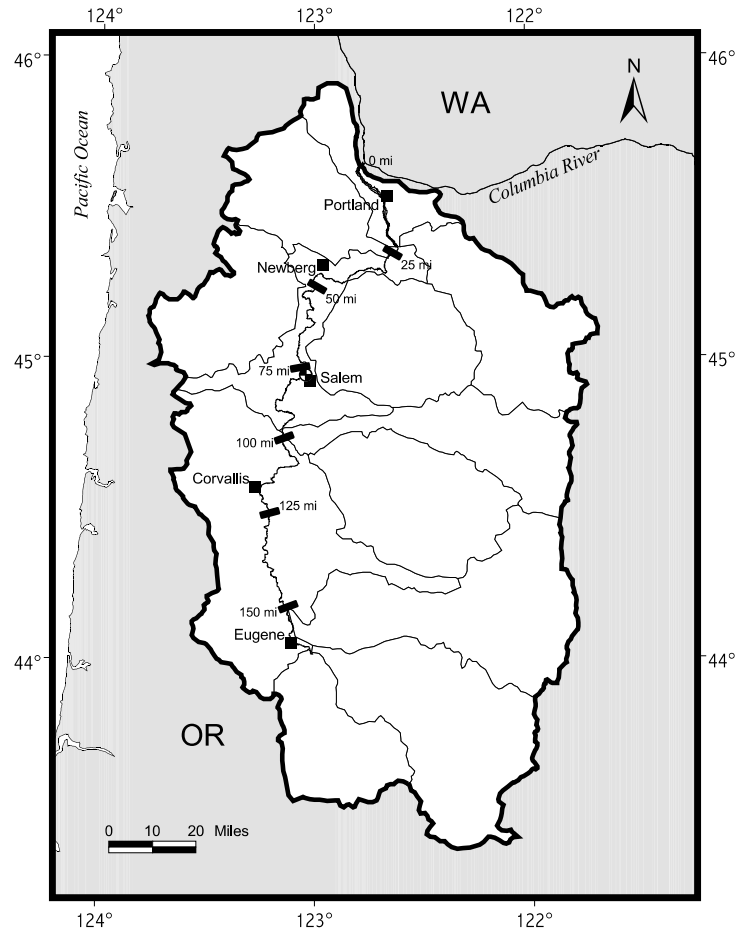


**Figure 13-1**

Hydrologic Region 17 and Willamette watersheds.

**Figure 13-2**

Location map of Willamette River Basin. River miles shown are distances from the confluence of the Willamette River with the Columbia River at Portland, OR.



The Willamette River was once one of the Nation's most grossly polluted waterways because of raw sewage discharges and inadequate levels of municipal and industrial waste treatment. Since the late 1920s, when a survey found that nearly half of the citizens of Portland were in favor of antipollution laws, public opinion in Oregon has strongly favored regulatory controls on waste discharges to clean up the Willamette River. As a result of strong legislative actions with overwhelming public support, the cleanup has become a major national environmental success. In particular, Oregon's legislative actions mandating a minimum level of secondary waste treatment have played an important role in restoring the ecological balance of the Willamette.

## Physical Setting and Hydrology

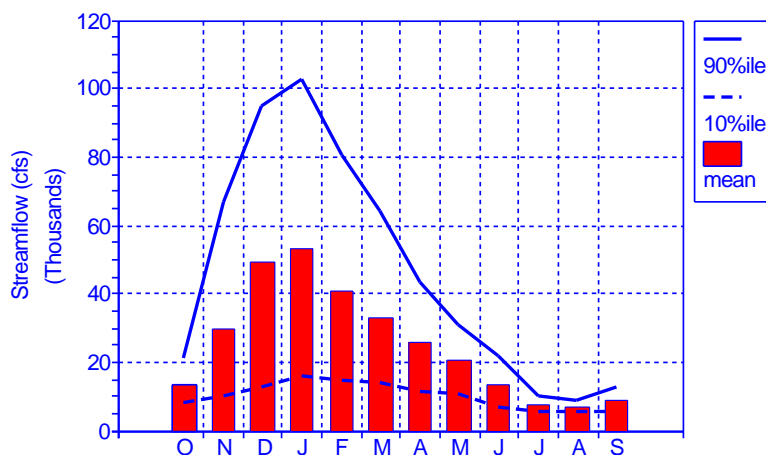
With a watershed of 11,200 square miles, the Willamette River basin in northwestern Oregon is bounded by the Coast (west) and Cascade (east) mountain ranges which have a north-south length of 150 miles and an east-west width of 75 miles (Figure 13-2). Elevations range from less than 10 feet at the mouth

**Table 13-1.** Physical characteristics of Willamette River at 6,000 cfs.  
Source: Rickert et al., 1976.

Reach	Length (miles)	Average Velocity (cm/sec)	Travel Time (days)
Upstream	135.0	60	2.8
Newberg Pool	25.5	8	3.9
Tidal	26.5	3	10.0

near the Columbia River to 450 feet in the valley near Eugene to greater than 10,000 feet in the headwaters of the Cascade mountain range. Physical transport in the river can be described in terms of three distinctive physiographic reaches and characterized by the key physical parameters that strongly influence water quality—length, summer low-flow velocity, and travel time (Table 13-1). The longer travel time in the tidal portion of the Willamette River (10 days) can lead to decreased water quality.

Seasonal variation in the river flow is the result of the region's heavy winter rains and spring snowmelt from November through March. Low-flow conditions occur during the summer months of July through September, with the seasonal minimum occurring during August. Based on data from 1940-1990, monthly average flows range from 6,246 cfs in August to 48,060 cfs in January (Figure 13-3). Before 1953, the natural summer low flow ranged from 2,500 cfs to 5,000 cfs at Salem. Since 1953 flow augmentation by 14 U.S. Army Corps of Engineers (USACE) reservoirs has been used to maintain a summer low flow of about 6,000 cfs at Salem (Hines et al., 1976) (Figure 13-4).



**Figure 13-3**

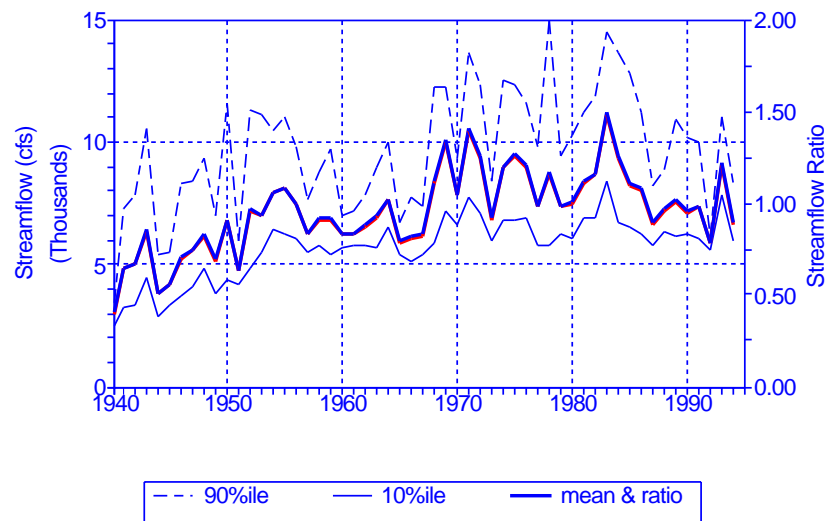
Monthly variation of flow of the Willamette River at Salem, Oregon (Gage #14191000), 1951-1980.

Source: USGS, 1999.

**Figure 13-4**

Long-term trends of summer flow of the Willamette River at Salem, Oregon (Gage #14191000), July-September.

Source: USGS, 1999.



## Population, Water, and Land Use Trends

Because of abundant natural resources, the river has played a key historical role in the agricultural and industrial development of the valley. The Willamette River, a major source for the basin's municipal (20 cities) and industrial (600 facilities) water supply, also provides irrigation water for the rich fruit and vegetable farms of the valley. Other major uses include commercial navigation, hydroelectric power production, commercial and recreational fisheries, and water-based recreational activities, including aesthetic enjoyment of the Greenway Trail along the length of the river. As the region has grown, the river has also been used—and misused—for municipal and industrial waste disposal, including the disposal of wastewater generated by the pulp and paper industry since the 1920s.

Oregon's three largest cities—Salem, Portland, and Eugene—with a total population of 1.8 million (nearly 70 percent of the state's population) are within the Willamette River basin. The population of the basin has steadily increased since World War II. With a significant wood products and agricultural economy, the Willamette basin accounts for about 70 percent of the total industrial production of Oregon. Industrial production, like the population of the basin, has steadily increased over the past several decades.

The Willamette River case study area includes a number of counties identified by the Office of Management and Budget (OMB) as Metropolitan Statistical Areas (MSAs) or Primary Metropolitan Statistical Areas (PMSAs). Table 13-2 lists the MSAs and counties included in this case study. Figure 13-5 presents long-term population trends (1940-1996) for the counties listed in Table 13-2. From 1940 to 1996 the population in the area more than tripled (Forstall, 1995; USDOC, 1998).

**Table 13-2.** Metropolitan Statistical Area (MSA) counties in the Willamette River case study. *Source: OMB, 1999.*

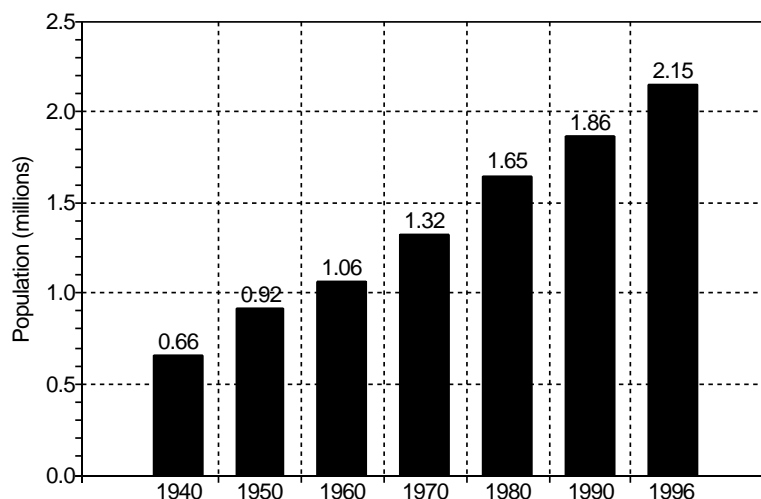
*Portland-Salem, OR-WA CMSA*

Clackamas, OR  
Columbia, OR  
Multnomah, OR  
Washington, OR  
Yamhill, OR

Clark, WA  
Marion, OR  
Polk, OR

*Corvallis, OR MSA*

Benton, OR



**Figure 13-5**

Long-term trends in population in the Willamette River Basin.

*Sources: Forstall, 1995; USDOC, 1998.*

## Historical Water Quality Issues

In the early 1920s, the Oregon Board of Health determined that the Lower Willamette River near Portland was grossly polluted as a result of raw waste discharges from municipal and industrial sources. In 1927, the Portland City Club declared the Willamette “ugly and filthy” with “intolerable” conditions. The first comprehensive water quality survey in 1929 found severely declining oxygen levels downstream of Newberg with an estimated concentration of 0.5 mg/L at the confluence with the Columbia River. Not surprisingly, bacteria levels were also found to be significantly increased downstream of each major city along the river. Industrial disposal from pulp and paper mills had resulted in extensive bottom sludge deposits that frequently surfaced during summer low-flow conditions as noxious, unsightly floating mats of sludge. By 1930 the municipal waste from the 300,000 inhabitants of Portland flowed untreated into Portland Harbor, resulting in severe oxygen depletion during the summer (Oregon State Sanitary Authority, 1964; Gleeson, 1972).

During the 1950s Kessler Cannon, a state official, described the Willamette River from Eugene to the Columbia River as the “filthiest waterway in the Northwest and one of the most polluted in the Nation.” Gross water pollution conditions resulted in high bacteria counts, oxygen depletion, and fish kills (e.g., Gleeson and Merryfield, 1936; Merryfield et al., 1947; Merryfield and Wilmot, 1945). Cannon recounted the noxious conditions in the Willamette: “As the

bacteria count rose, oxygen levels dropped—to near zero in some places. Fish died. The threat of disease put a stop to safe swimming. Rafts of sunken sludge, surfacing in the heat of summer, discouraged water-skiing and took the pleasure out of boating” (Starbird and Georgia, 1972). In 1967 the Izaak Walton League described the Lower Willamette River as a “stinking slimy mess, a menace to public health, aesthetically offensive, and a biological cesspool” (USEPA, 1980).

## **Legislative and Regulatory History**

After more than a decade of public concern about the polluted conditions of the Willamette River, the citizens of Oregon passed a referendum in 1938 setting water quality standards and establishing the Oregon State Sanitary Authority. With the establishment of the Sanitary Authority, it became Oregon’s public policy to restore and maintain the natural purity of all public waters. As a result of regulatory actions by the Sanitary Authority, all municipalities discharging into the Willamette implemented primary treatment during the period from 1949 to 1957, with all costs borne by the municipalities. Beginning in 1952 industrial waste discharges from the pulp and paper mills were controlled by required lagoon diversions during summer months. In 1953 the new USACE dams began to operate, resulting in augmentation of the natural summer low flow. Although not originally planned for water quality management, summer reservoir releases have become a significant factor in maintaining water quality and enabling salmon migration during the fall.

Although tremendous accomplishments had been made in controlling water pollution in the Willamette basin, large increases in industrial production and in the population served by municipal wastewater plants exceeded the assimilative capacity of the river. By 1960 the Sanitary Authority required that all municipalities discharging to the Willamette River achieve a minimum of secondary treatment (85 percent removal of BOD<sub>5</sub>). In 1964 the pulp and paper mills were directed to implement primary treatment, with secondary treatment during the summer months. In 1967, industrial secondary treatment was required on a year-round basis. The Sanitary Authority had thus established a minimum policy of secondary treatment for all municipal and industrial waste dischargers with the option of requiring tertiary treatment if needed to maintain water quality. The state initiated the issuance of discharge permits for wastewater plants in 1968, 4 years before the 1972 CWA established the National Pollutant Discharge Elimination System (NPDES). The policy adopted in 1967 remains the current water pollution control policy of the state of Oregon for the Willamette River (ODEQ, 1970).

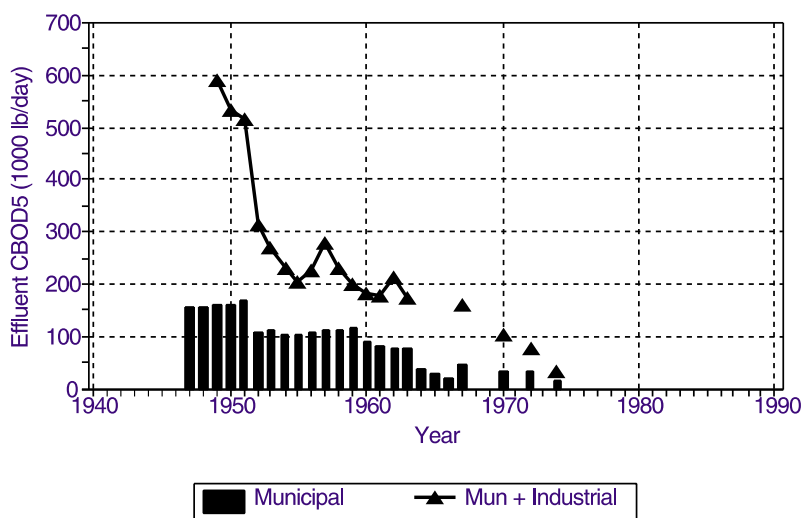
In response to the 1965 Federal Water Quality Act, Oregon established intrastate and interstate water quality standards in 1967 that were among the first new state water quality standards to be approved by the federal government. The 1972 CWA provided even further authority for Oregon to issue discharge permits limiting the pollutant loading of municipal and industrial facilities.

From 1956 to 1972, Federal Construction Grants to Oregon totaled \$33.4 million for municipal wastewater facilities (CEQ, 1973). Since 1974 the cities of Salem, Corvallis, and Portland have received Construction Grants under the 1972 CWA to build and upgrade secondary waste treatment facilities.

## Impact of Wastewater Treatment: Pollutant Loading and Water Quality Trends

As a result of the stringent regulatory requirements for municipal and industrial waste treatment, total pollutant loading has decreased substantially over the past 30-40 years (Figure 13-6) while total wastewater flow has increased over the same period. By 1972, when the CWA was passed, the total oxygen demand of wastewater discharges to the Willamette had been decreased to 25 percent of the demand of the pollutant load discharged in 1957 (CEQ, 1973). Following the implementation of basinwide secondary treatment for municipal and industrial wastewater sources, water quality model budgets have shown that about 46 percent of the oxygen demand in the Willamette River during the critical summer months results from upstream nonpoint source loads from rural tributary basins. The remaining half of the total oxygen demand is accounted for by municipal (22 percent) and industrial (32 percent) point source loads (Rickert and Hines, 1978).

Severe summer oxygen depletion has been the key historical water quality problem in the Willamette River. Over the past 20 years, however, summer oxygen levels have increased significantly as a result of (1) the implementation of basinwide secondary treatment for municipal and industrial point sources and (2) low flow augmentation from reservoir releases. Based on data obtained from the earliest water quality survey in 1929 to the most recently available monitoring programs, the dramatic improvements in summer oxygen levels in the river are clearly shown in the spatial distribution of oxygen from Salem to Portland Harbor (Figure 13-7) and the long-term historical trend for oxygen in the lower Willamette River near Portland Harbor (Figure 13-8). These historical data sets document the grossly polluted water quality conditions that existed prior to implementation of a minimum level of secondary treatment for municipal and industrial discharges to the river.



**Figure 13-6**

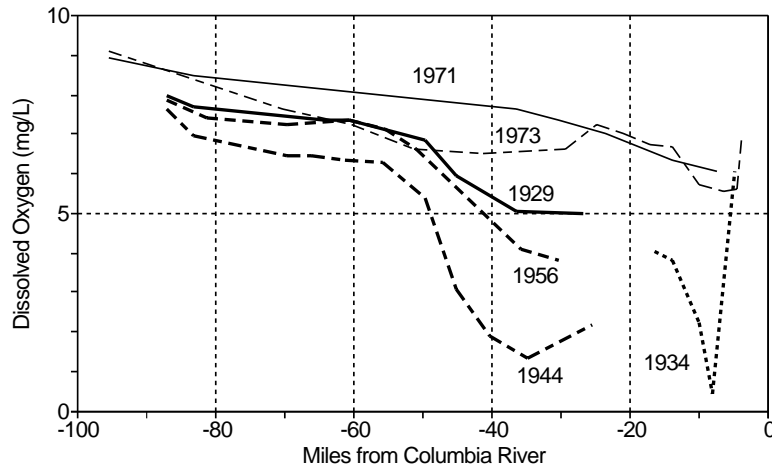
Long-term trends in municipal and industrial effluent BOD<sub>5</sub> loading to the Willamette River.

Source: Gleeson, 1972; ODEQ, 1970.

**Figure 13-7**

Long-term trends in the spatial distribution of DO in the Willamette River.

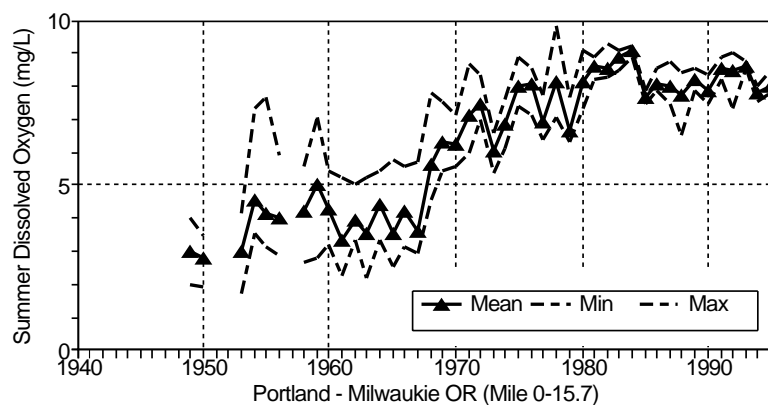
Source: Rickert, 1984.



**Figure 13-8**

Long-term trends in summer DO in the Lower Willamette River at Portland, OR, for RF reach 17090012017 (mile 0-15.7).

Source: USEPA (STORET).



Although the current status of the river is visibly much improved and water contact sports and salmon migration are once again possible in most of the river, there are still concerns about the levels of toxic contamination. Oregon's 1990 water quality status assessment report (ODEQ, 1990a) classified the river as "water quality limited" as a result of seven contaminants exceeding USEPA draft sediment guidelines (arsenic, chromium, lead, zinc, and DDT), state water quality standards (arsenic), or both (2,3,7,8-TCDD). Surveys have found levels of toxic chemicals in water, sediments, and fish tissue at various locations in the river basin (ODEQ, 1994). Surveys conducted by ODEQ in 1994 indicated that levels of metals (arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc), pesticides (chlordane and DDT), other organic chemicals (carbon tetrachloride, creosote, dichloroethylene, dioxin, PAHs, PCBs, phenol, pentachlorophenol, phenanthrene, phthalates, trichloroethane, trichloroethylene, and trichlorophenol), and bacteria exceed regulatory or guidance criteria for the protection of aquatic life and human health in at least one location of the river.

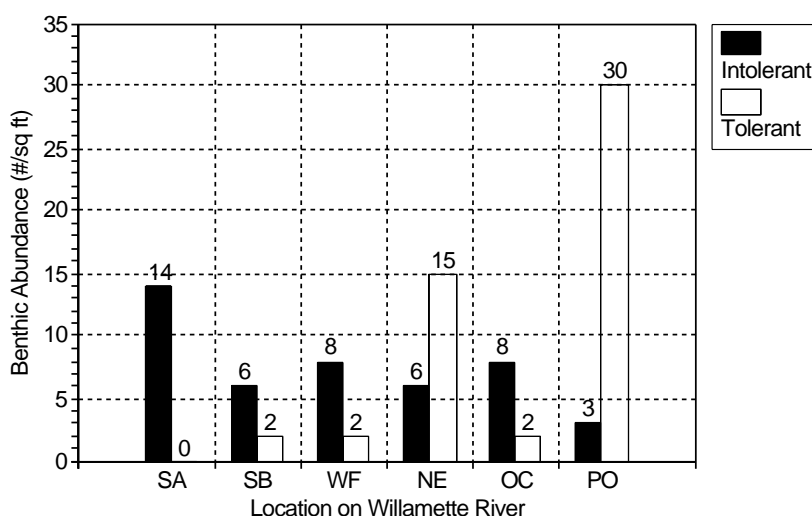
As a result of these findings, in 1990 the Oregon legislature directed ODEQ to develop a comprehensive study that would generate a technical and regulatory understanding and an information base on the river system that could be used to protect and enhance its water quality. To meet this directive, ODEQ developed and implemented a comprehensive, multiphase investigation known as the Willamette River Basin Water Quality Study (WRBWQS) (ODEQ, 1990b; Tetra Tech, 1995).



## Impact of Wastewater Treatment: Recreational and Living Resources Trends

The first comprehensive study of the Willamette River biota was conducted by Dimick and Merryfield (1945) in the summer of 1944. Their study was specifically intended to assess the impact of water pollution on fish and benthic invertebrates in the river. Benthos are particularly good indicators of long-term trends in water quality because most benthic species are sedentary and have long life spans. Their state of health is therefore a gauge of both past and present water quality. Reactions to even occasional toxic discharges are measurable as variances in the species assemblages of benthic invertebrates. For pollution studies, benthos are divided into three categories: (1) intolerant species (e.g., stoneflies, mayflies, caddisflies) are indicative of good water quality because of their inability to survive in or tolerate low DO concentrations; (2) facultative species are indicative of a transition between good and poor water quality because they can survive under a wide range of DO conditions; and (3) tolerant species (e.g., sludgeworms), which are adapted to low DO levels, become dominant where poor water quality is prevalent.

Dimick and Merryfield (1945) found very different biological conditions in different stretches of the river. Upstream of Salem, where pollutant sources to the river were few, they found an abundance of healthy fish and populations of intolerant caddisfly, mayfly, and stonefly nymphs (Figure 13-9). From below Salem to Portland, where pollutant loadings to the river were greatest, they found few to no fish, dead fish in or on the banks of the river, and a total absence of stoneflies and mayflies. They further noted that the biomass of insect larvae downstream of Salem was less than that upstream, and that largemouth bass collected below Salem were generally smaller than normal and in poor physical condition. Both of these conditions are indicative of poor water quality.



**Figure 13-9**

Spatial distribution of tolerant and intolerant benthic organisms in the Willamette River upstream and downstream of municipal waste discharges in 1945.

Source: Dimick and Merryfield, 1945.

SA=Salem (1 mile above city); SB=Salem (2 miles below city); WF=Wheatland Ferry; NE=Newberg (0.8 miles above city); OC=Oregon City (above and below Willamette Falls); PO=Portland (0.3 miles upstream of Sellwood Bridge).

Dimick and Merryfield attributed the poor biological condition below Salem to the effects of pollution, but it is uncertain whether fish were directly affected or whether their populations were diminished because of the lack of their invertebrate foodstuffs (Dimick and Merryfield, 1945). Regardless, the study demonstrated that pollution was a major factor in the decline of the river's commercial and sport fisheries.

In 1983 the study was repeated to assess the changes that had occurred in the river since its cleanup began. Hughes and Gammon (1987) sampled the same sites that Dimick and Merryfield had sampled in 1944. Although the 1983 study showed some signs of a pollution-stressed river below Salem, the differences between the findings of the studies demonstrated a marked improvement in water quality. Where Dimick and Merryfield had found only tolerant species associated with sluggish, warm water and muddy or sandy substrates, Hughes and Gammon found many intolerant species suited to fast-moving, cold water and rubble and gravel bottoms.

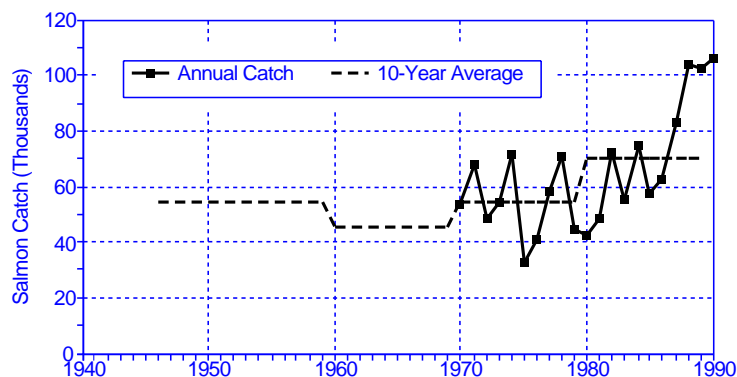
The improvements in the fish communities of the Willamette River between 1944 and 1983 (Figure 13-10) were not solely due to water quality improvements. Historically, the river provided important spawning and nursery grounds for salmon and steelhead, but dams built along the river prevented these fish from reaching their spawning grounds. Corrections to this situation have accompanied water quality improvements. Fish ladders have been built at dams, and four large fish hatcheries have been put into operation, producing 3.8 million salmon per year (Bennett, 1991). The dams also provide flow augmentation during autumn low-flow periods, thereby providing faster moving, oxygenated water to running fall chinook salmon (Starbird and Georgia, 1972).

Water quality has nevertheless played an important role in the survival and return of both natural-born and hatchery-reared salmon in the Willamette River. In 1965 only 79 chinook salmon were counted in the fall run. That number increased to 5,000 in 1971 (Starbird and Georgia, 1972). A record high of 106,300 spring chinook salmon were counted in the 1990 run, up 30 percent from the 1985-1989 average of 81,900. The 1990 catch of chinook salmon of 27,700 was 39 percent greater than the 1980-1989 average of 20,000 (Bennett, 1991). With the recent and continuing population growth in the Portland area (where most of the salmon are caught) and water quality improvements, interest in angling in the river has increased dramatically. The Willamette River is once again able to support important commercial and recreational fisheries.

**Figure 13-10**

Long-term trends of spring chinook salmon runs.

Source: Bennett, 1991.



## Summary and Conclusions

The cleanup of the Willamette River has been accomplished because of overwhelming public support; strong commitment by federal, state, and local governments; comprehensive water quality studies that documented the extent of the problems; and the implementation of sound engineering proposals for controlling water pollution. Public pressure and responsive political leadership have resulted in the basinwide implementation of secondary treatment requirements with a minimum of legal actions needed to ensure compliance with the regulations. Water quality studies of the Willamette (e.g., Rickert, 1984; Rickert et al., 1976) have demonstrated the importance of the minimum requirement of secondary waste treatment for municipal and industrial dischargers, as well as the significance of background water quality and summer low-flow augmentation from USACE reservoirs, in achieving Oregon's water quality goals.

Vast improvements in the water quality of the Willamette River, facilitated by stringent regulatory controls, have led to remarkable improvements in the integrity of the river's biological communities. Of major importance, both recreationally and economically, is the continuing recovery of the fisheries. Salmon and steelhead on their migratory spawning runs are no longer precluded from reaching their spawning grounds in the Willamette River basin because of severely depressed or nonexistent concentrations of DO. Recreational anglers are once again able to enjoy pursuing these valuable gamefish as the fish make their way up the river to their spawning grounds. Another significant improvement is the return of viable populations of resident species of gamefish, including bass, catfish, perch, sturgeon, and crappies.

Although the severe water quality problems that have plagued the Willamette River in the past are clearly gone, there are still reasons for concern about the river's overall health (Tetra Tech, 1995). Until the continued presence of toxic contaminants in the water and sediments, the loads of suspended sediment and nutrients, and the alteration of the habitat can be abated, the overall ecological conditions of the Willamette River will continue to suffer.

For four decades beginning in the 1920s the Lower Willamette River near Portland, Oregon, was considered one of the most polluted urban-industrial rivers in the United States. In 1927 the Portland City Club declared the Willamette River "ugly and filthy...with intolerable conditions." During the 1950s the Willamette River was described as the "filthiest waterway in the Northwest and one of the most polluted in the Nation." In 1967 the Izaak Walton League described the river as a "stinking slimy mess, a menace to public health, aesthetically offensive and a biological cesspool."

Three decades after enactment of strict water pollution control regulations by the state of Oregon in the late 1960s and the federal Clean Water Act in 1972, the remarkable improvements in water quality and the ecological health of the river now provide important recreational and commercial benefits to the citizens of the Willamette valley. Salmon and steelhead fisheries, once blocked by dams without fish ladders and constrained by low dissolved oxygen conditions, are now sustained by migratory populations that can safely reach upriver spawning grounds. The local economies of major cities on the Willamette River are thriving, and upscale developments are attracted to riverfront locations by the aesthetics of a clean river that was once considered noxious with an unsightly riverfront.

Although the gross water pollution problems of the first half of the 20th century have been eliminated, nutrient enrichment, sediment loading, and the lingering presence of toxic chemicals in the river, sediment bed, and biota are ecological problems that remain. Hopefully, they will be addressed in the early decades of the 21st century.

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